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RUNNING HEAD: Falls prevention for older adults after hospital

TITLE: Reducing falls in older adults recently discharged from hospital: A systematic review and meta-analysis.

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AUTHORS:

Chiara Naseri,¹ B. Sc (Physiotherapy)

Terry P Haines,² PhD

Christopher Etherton-Beer,³ PhD

Steven McPhail,^{4,5} PhD

Meg E Morris,⁶ PhD

Leon Flicker,⁷ PhD

Julie Netto,⁸ PhD

Jacqueline Francis-Coad,⁹ PhD

Den-Ching A Lee,² PhD

Ronald Shorr,^{10,11} PhD

Anne-Marie Hill,¹ PhD

This study was conducted at Curtin University, Faculty of Health Science, School of Physiotherapy and Exercise Science.

Author institutional affiliations:

1. School of Physiotherapy and Exercise Sciences, Faculty of Health Science, Curtin University, Perth, Western Australia
2. Faculty of Medicine, Nursing and Health Science, Monash University, Melbourne, Victoria
3. Department of Geriatric Medicine, School of Medicine and Pharmacology, Royal Perth Hospital Unit, University of Western Australia, Perth, Western Australia
4. School of Public Health and Social Work, Faculty of Health, Queensland University of Technology
5. Centre for Functioning and Health Research, Metro South Health, Brisbane, Queensland
6. Healthscope & La Trobe Centre for Sport & Exercise Medicine Research, La Trobe University, Victoria, Australia
7. Western Australian Centre for Health & Ageing, Centre for Medical Research, University of Western Australia, Perth, Western Australia
8. School of Occupational Therapy and Social Work, Faculty of Health Science, Curtin University, Perth, Western Australia
9. School of Physiotherapy, Institute for Health Research, The University of Notre Dame Australia, Fremantle, Western Australia
10. Malcom Randall VA Medical Center, Geriatric Research Education and Clinical Center (GRECC),
11. College of Medicine, University of Florida, Gainesville, Florida USA

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Corresponding author from whom reprints can be obtained:

Chiara Naseri

School of Physiotherapy and Exercise Science

Faculty of Health Science, Curtin University

GPO Box U1987

Perth, Western Australia 6845

chiara.naseri@postgrad.curtin.edu.au

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IMPACT STATEMENT

We certify that this work is novel.

The potential impact of this research on clinical care or health policy includes the following:

- a vigorous and in-depth review of available evidence of effective falls prevention interventions for older adults recently discharged from hospital.
- provides clinical recommendations based on GRADE evidence and is clinically relevant for broad multidisciplinary geriatric healthcare.
- substantially adds to existing discharge care guidelines for older adults and clarifies the gaps in the evidence for future research opportunities.
- a new perspective for advancing geriatric rehabilitation, improving the quality of life of older adults and advancing the efficiency of healthcare.

ABSTRACT

BACKGROUND: Older adults are known to have increased falls rates and functional decline following hospital discharge, with substantial economic health care costs. This systematic review aimed to synthesise the evidence for effective falls prevention interventions in older adults recently discharged from hospital.

METHODS: Literature searches of 6 databases of quantitative studies conducted from 1990 to June 2017, reporting falls outcomes of falls prevention interventions for community-dwelling older adults discharged from hospital were included. Study quality was assessed using a standardized JBI critical appraisal tool (MAStARI) and data pooled using Rev-Man Review Manager®

RESULTS: Sixteen studies (total sample size N= 3290, from 8 countries, mean age 77) comprising 12 interventions met inclusion criteria. We found home hazard modification interventions delivered to those with a previous falls history (1 study), was effective in

reducing the number of falls (RR 0.63, 95%CI 0.43, 0.93, Low GRADE evidence). Home exercise interventions (3 studies) significantly increased the proportion of fallers (OR 1.74, 95%CI 1.17, 2.60, Moderate GRADE evidence), and did not significantly reduce falls rate (RR 1.27, 95%CI 0.99, 1.62, Very Low GRADE evidence) or falls injury rate (RR 1.16, 95%CI, 0.83,1.63, Low GRADE evidence). Nutritional supplementation for malnourished older adults (1 study) significantly reduced the proportion of fallers (HR 0.41, 95% CI 0.19, 0.86, Low GRADE evidence).

CONCLUSION: The recommended falls prevention interventions for older adults recently discharged from hospital are to provide home hazard minimisation particularly if they have a recent previous falls history and consider nutritional supplementation if they are malnourished.

KEY WORDS: falls prevention interventions; after hospital discharge; falls outcomes; older adults; systematic review

INTRODUCTION

Implementing effective strategies to reduce falls among older adults has become a world-wide health challenge as the global population continues to age. [1] Falls are a leading cause of hospitalisation for older adults. [2, 3] Hospital length of stay is decreasing, leaving older adults at risk of adverse events following hospital discharge. Falls are known to increase among older adults during the post-discharge period with an increased risk of hip fracture.[4-6] Compared to the average annual fall rate of 30% in the general older community with 10% of these falls resulting in a serious injury, [7-9] 40% of older adults recently discharged from hospital fall at least once in the 6-month period following discharge and 54% of these falls result in a serious injury. [10-14]

Several large systematic reviews have established evidence for the effectiveness of falls prevention interventions for older adults in the general community. [15-20] However, the studies included in these reviews did not specifically evaluate interventions in the post-discharge period and the findings may not translate to falls prevention among community-dwelling older adults recently discharged from hospital. Systematic reviews of interventions that provided broad discharge support for older adults showed limited reduction in falls or adverse events. [21,22] One systematic review that evaluated falls prevention education for older adults concluded there was some evidence that education was effective in reducing falls rates during and after hospitalisation (risk ratio [RR] 0.77, 95% confidence interval 0.69 to 0.87), however other falls prevention interventions were not examined. [23] The lack of research evidence regarding effective falls prevention interventions in the period following hospitalisation needs to be addressed.

The primary objective of this review was to collate randomised controlled trials (RCTs) that delivered falls prevention interventions for older adults just prior or immediately following hospital discharge, and to synthesise the evidence regarding their effectiveness during the 6 months immediately following hospital discharge.

METHODS

A review was undertaken according to a protocol published in JBI Register of Systematic Reviews and Implementation Reports, [24] and reported in accordance with PRISMA guidelines. [25]

Search strategy and information sources

The search was undertaken using a three-step strategy recommended by the JBI systematic review library, [26] using MeSH terminology and keywords to ensure all relevant studies were captured. Full details of the search strategy and information sources can be found in Supplementary Appendix 1 available in *Age and Ageing* online from the journal website.

Inclusion Criteria

This review examined studies that evaluated any falls prevention intervention delivered to adults 60 years of age or older who were hospitalised and then discharged to the community. The interventions must have been delivered/commenced in hospital or in the first month after hospital discharge from hospital. [24] Studies eligible for the review were published and unpublished studies written in English from any country between January 1990 and June 2017, including RCTs and pseudo-RCTs comparing interventions against no intervention or placebo control. The start date of 1990 was considered appropriate as research concerning falls prevention is a relatively recent field and other large systematic reviews investigating falls interventions include RCTs dated from 1990. [27] Studies needed to measure a falls outcome within at least 6 months after discharge from hospital including falls rate (expressed per 1000-person days), proportion of people who fell one or more times, injurious falls rate (expressed per 1000-person days) or proportion of people who had one or more injurious falls, with consideration of ProFANE common set of falls outcome definitions and measures. [28-33]

Study quality

Papers selected for critical appraisal were assessed by three independent reviewers for risk of bias and methodological quality. [26] This was completed prior to inclusion in the review, using the standardised critical appraisal from JBI Meta-Analysis of Statistics Assessment and

Review Instrument (JBI-MASARI), found in Supplementary Appendix 2 available in *Age and Ageing* online from the journal website.

Data Synthesis and Analysis

Data was collated by one reviewer then three reviewers independently confirmed accuracy of the data synthesis. Effectiveness of interventions was classified according to outcomes. [33,34] For outcomes reported as rates (rates of falls and rate of injurious falls), data were pooled using inverse variance DerSimonian and Laird method. [35] This produced a relative rate effect size with 95% confidence intervals (CI). For outcomes measured as proportions, the number of fallers and non-fallers in each group were entered and data pooled using Mantel-Haenszel model. [36] This produced an odds ratio (OR) with 95% confidence intervals. For studies that employed factorial designs, we extracted the main effect of each intervention if no interaction effect was identified. Quantitative data were pooled in statistical meta-analysis using Rev-Man Review Manager (Version 5.3.2014 TM) to generate forest plots. [37] All studies were analysed in terms of falls outcomes and sub-group meta-analyses based on pooling of comparable interventions. Heterogeneity was assessed using the I² statistic and visual inspection of forest plots. A fixed-effects model was used to calculate estimates, based on examination of the literature. [26, 38, 39] The criteria that guided our decision to use the fixed-effect model in meta-analysis was the small number, size and heterogeneity of the studies evaluating each falls intervention. The included studies were clinical trials, methodologically homogenous, and measured one common true effect, a falls outcome. The only possible exception within this criterion was potential between-study heterogeneity of the participants. Notwithstanding fulfilment of our study sample inclusion criteria, we reasonably considered the participants to be similar enough to appropriately represent the population of older people recently discharged from hospital. [39]

RESULTS

Selected Studies

The search generated 1068 articles from the six databases. Figure 1 illustrates the study selection process. Supplementary Appendix 3, available in *Age and Ageing* online outlines the characteristics of included (n=16) studies.

The articles included in the review comprised one quasi RCT and 15 RCTs, [14, 40-54] please refer to Supplementary Appendix 4 for the full reference list of included studies, available in *Age and Ageing* online. All the selected studies' sample populations consisted of older adults recruited from inpatient wards. Participants' mean age across the 16 studies were 77 years, with an age range of 70-84. Further details regarding the study population can be found in Supplementary Appendix 5, available in *Age and Ageing* online.

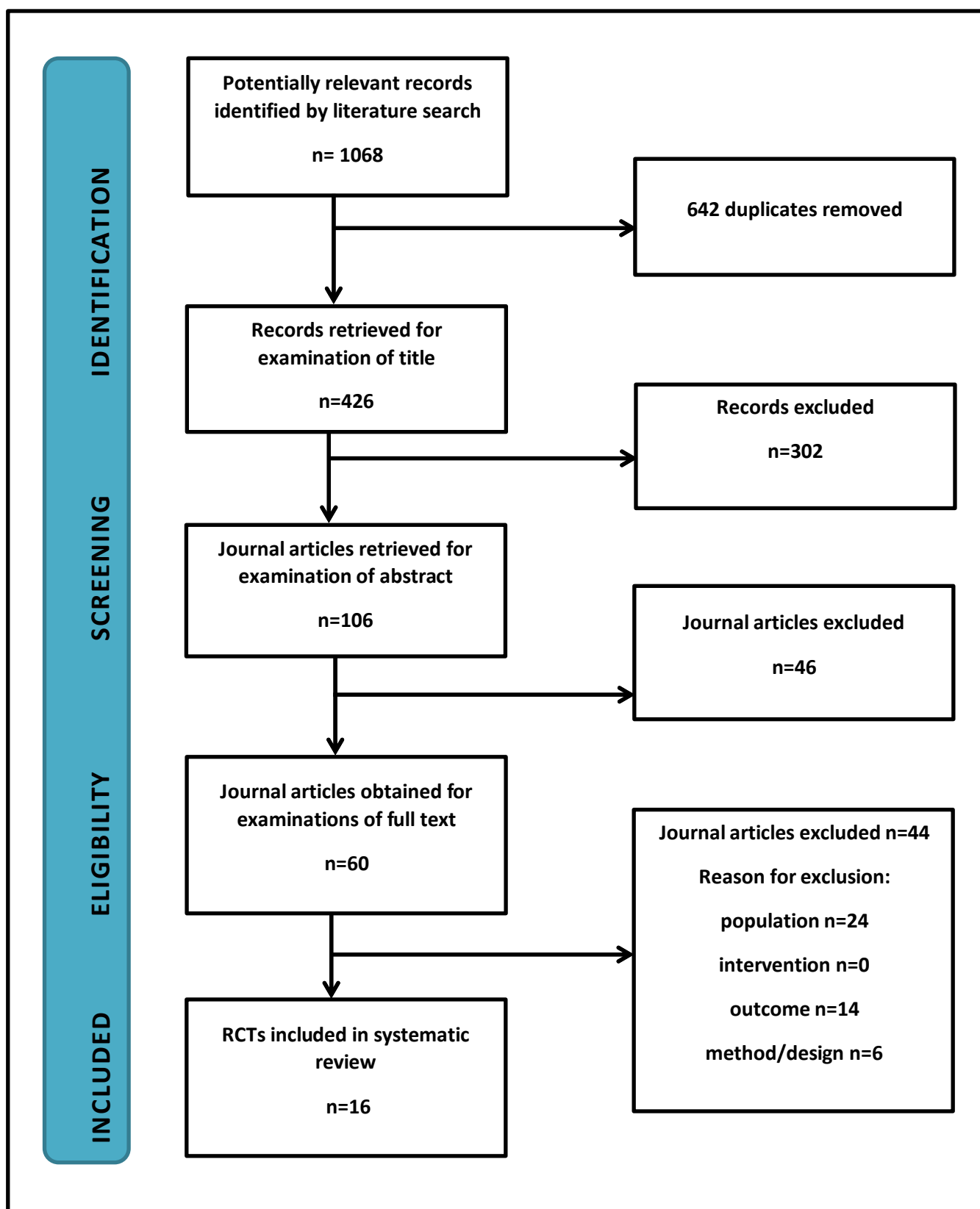


Figure 1. Study Selection Flow Chart

Study Interventions

The interventions from 9 studies were grouped according to a recommended taxonomy to describe falls-prevention interventions, [29] including home hazard modification interventions, home exercise program, and cholecalciferol therapy. Two studies delivered exercise and cholecalciferol in factorial designed RCTs. [48, 52] One study provided a home exercise intervention as well as multifactorial falls risk minimisation strategies based on falls risk factors, [54] identified using a falls risk assessment tool for older people in the community (FROP-Com). [55, 56].

There were 8 interventions included in the review that could not be pooled in meta-analysis because they only featured once across all the studies. These were geriatric team management, inpatient falls prevention education, tailored falls prevention education prior to discharge, a day hospital balance class, high intensity quadriceps exercise, nutritional supplementation, discharge planning, and an inpatient balance circuit class.

Quality of studies

The critical appraisal of all 16 included studies can be found in Supplementary Appendix 6, available in *Age and Ageing* online from the journal website.

Effectiveness of falls prevention interventions

Home hazard modification intervention

Three trials evaluated the effect of home hazard modification interventions on falls outcomes, however they differed in their presentation of effect estimates, therefore their results were

analysed at the individual study level. One study dichotomised falls data, showing no significant effect on proportion of fallers (relative risk 1.06, 95%CI, 0.48, 2.34). [47] Another study used the Andersen-Gill approach to describe falls as recurrent events and showed a significant reduction in proportion of fallers for the subgroup of participants with a previous falls history (HR 0.75, 95%CI 0.58, 0.96). [42] (Supplementary Appendix 7 Figure S1, available in *Age and Ageing* online)

In another home hazard modification intervention study, results showed a reduction in falls using rate ratio (RR), also for a subgroup of participants with a previous history of frequent falls (RR 0.63, 95%CI 0.43, 0.93). [43] (Supplementary Appendix 7 Figure S2, available in *Age and Ageing* online)

Home exercise intervention

Meta-analysis of falls rate data from 3 studies in the home exercise group of interventions showed moderate heterogeneity ($I^2=32\%$ $p=0.23$), this may have been due to the differing doses of intervention and clinical variation in the populations across the studies. Overall the intervention did not significantly reduce falls (RR 1.27, 95%CI 0.99, 1.62), or falls injuries (RR 1.16, 95%CI, 0.83, 1.63), however meta-analysis from 2 studies found a significant increase in proportion of fallers (OR 1.74, 95%CI, 1.17, 2.60) (Figure.2).

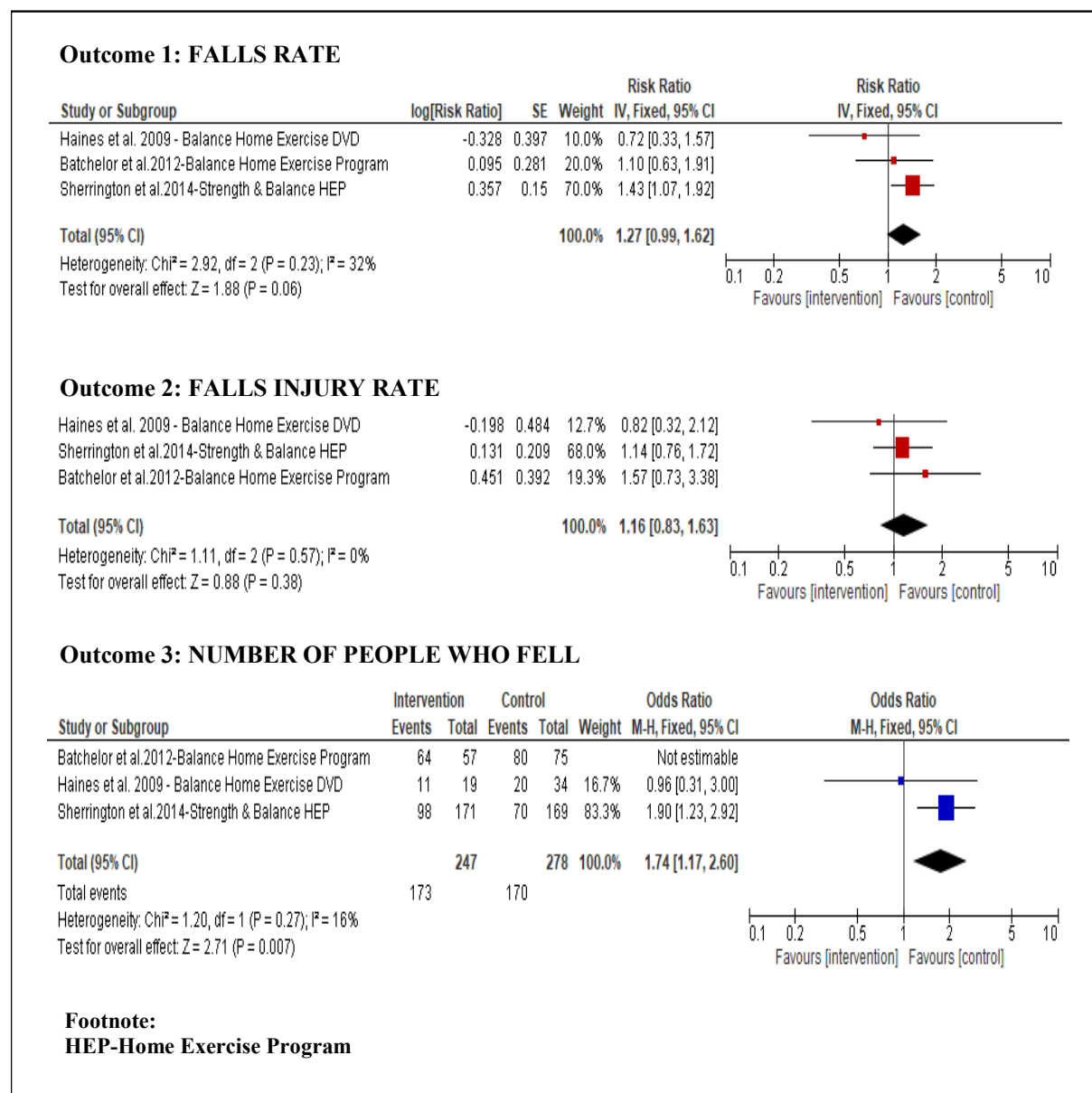


Figure 2. Forest Plots (Pooled) Overall Effect of Home Exercise on Falls Outcomes

Short-term nutritional supplementation intervention

A single study provided a multi-component nutritional intervention that included cholecalciferol supplementation for malnourished older adults commencing at hospital admission and continuing to 3 months after discharge. [50] Falls rates were treated as binary data (participants did/did not fall), describing the hazard ratio of patients experiencing one or

more falls, with an overall significant reduction in the number of people who fell (HR 0.41, 95% CI, 0.19,0.86) at the study level.

There were 6 further interventions analysed at the study level, these are described in Supplementary Appendix 8 available in *Age and Ageing* online. The interventions included cholecalciferol therapy, [48] inpatient falls prevention education [14] and education provided at discharge, [41] geriatric team management, [49] inpatient balance circuit training, [51] high-intensity quadriceps resistance training, [52] and day hospital strength and balance training. [46]

Overall comparison of effect of interventions (un-pooled)

The effects of all interventions, categorised according to studies, are presented using an un-pooled forest plot in Figure 3 (effect of all interventions on falls rates and proportion of people who fell). Six interventions were found to be ineffective in this population, including a single occupational therapist phone call, [47] a balance home exercise program using an instructional DVD, [53] a non-supervised strength and balance home exercise program, [55] an inpatient balance home exercise program, [51] cholecalciferol therapy, [48] and an inpatient falls education program. [14]

There was between study variation in GRADE quality of evidence for the effect of home exercise intervention on falls outcomes (Table 1), despite heterogeneity scores during meta-analysis being low (Figure 2). This could be related to the clinical variation across the studies population, including older people diagnosed as high falls risk following a recent stroke, and discharged from general surgical and medical wards (Supplementary Appendix 3). We would advise caution against overinterpreting the GRADE recommendation, and guide readers to

consider home exercise intervention content, dose, duration, delivery setting and supervision at the study level.

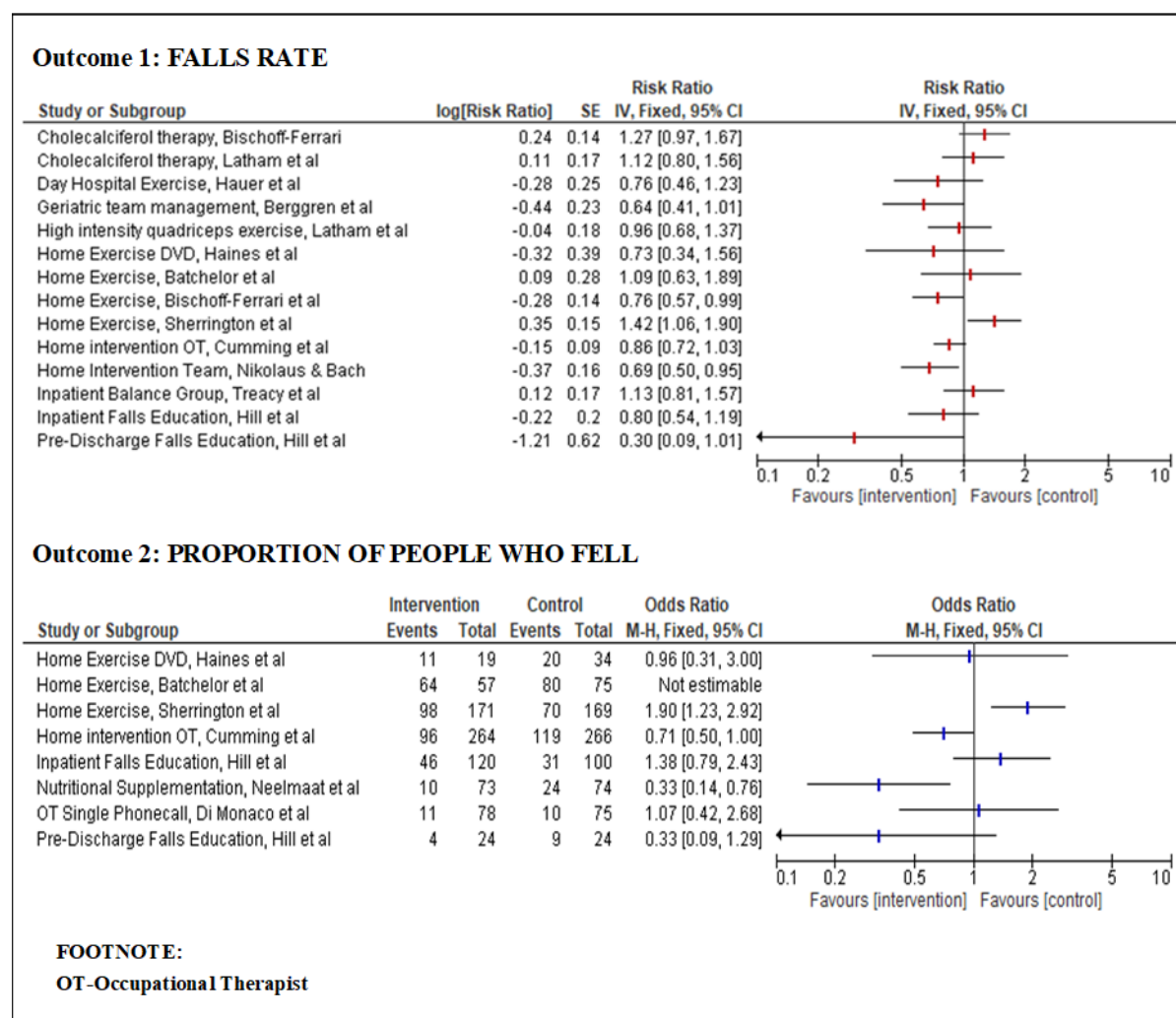


Figure 3. Un-pooled Effect of Interventions on Falls Rate and Proportion of People Who Fell

Recommendations based on the evidence

Table 1 illustrates the summary of the evidence using the GRADE approach. [57]

Table 1. GRADE Summary of the evidence

	Number of Participants (studies)	Quality of the evidence (GRADE)	ANTICIPATED ABSOLUTE EFFECT	
			Relative effects (%)	Absolute effect with intervention [95% CI]
HOME EXERCISE INTERVENTION				
Bibliography: Batchelor et al, (2012); Sherrington et al (2014); Haines et al (2009).				
Incident rate of falls Pooled	n= 525 participants (3 studies)	⊕⊕⊕⊕VERY LOW ^{1,2} due to inconsistency & imprecision	-	Risk ratio for falls in the intervention groups was 1.27 [0.99 to 1.62]
Incident rate ratio of falls injury rate Pooled	n= 525 (3 studies)	⊕⊕⊕⊕LOW ¹ due to imprecision	-	Risk ratio for falls injuries in the intervention groups was 1.16 [0.83 to 1.63]
Proportion of fallers Pooled	n= 369 (2 studies)	⊕⊕⊕⊕MODERATE	-	Odds ratio for proportion fallers with intervention v was 1.74 [1.17, 2.60]
NUTRITIONAL SUPPLEMENTATION				
Bibliography: Neelmaat et al (2012)				
Proportion of fallers	n= 210 (1 study)	⊕⊕⊕⊕LOW due to only 1 study	-	Hazard ratio for proportion of fallers with intervention was 0.41 [0.19, 0.86]

1 Imprecision: the 95% CI of the pooled estimate included 1 or no effect

2 Inconsistency: heterogeneity may be explained by the differing characteristics of the populations, content and duration of the intervention across the studies.

GRADE Working Group grades of evidence **High quality:** Further research is very unlikely to change our confidence in the estimate of effect. **Moderate quality:** Further research is likely to have an important impact on our confidence in the estimate of effect and may change the estimate. **Low quality:** Further research is very likely to have an important impact on our confidence in the estimate of effect and is likely to change the estimate. **Very low quality:** We are very uncertain about the estimate.

The **corresponding risk** (and its 95% confidence interval) is based on the assumed risk in the comparison group and the **relative effect** of the intervention (and its 95% CI).

GRADEpro GDT: GRADEpro Guideline Development Tool [Software]. McMaster University, 2015 (developed by Evidence Prime, Inc.). <http://www.grade-pro.org>. [Accessed 16th March 2017]

DISCUSSION

Summary of findings

The present systematic review and meta-analysis is the first to synthesize evidence of

effective falls prevention interventions for older adults following recent hospital discharge.

Overall results indicated there was limited evidence that home hazard modifications reduced

falls outcomes, though the intervention was more effective among a sub group of participants

who had a frequent falls history. Home hazard modifications have previously been found to

be effective in preventing falls among the general community population, [16] and are

frequently a component of hospital discharge plans. [58-60] These previous findings suggest that if these interventions were tailored and evaluated specifically for older adults recently discharged from hospital, there could be a greater amount of evidence of their effectiveness for falls prevention during the post-discharge period.

Previous evidence has shown that falls prevention exercise programs are beneficial for older adults in the community setting, [16, 18, 61] however the findings of this review indicate they may have a different effect in older adults recently discharged from hospital. There are many precipitating factors to be considered in providing home exercise falls interventions to older adults following hospital discharge, including the likely need for regular supervision over an extended period to increase safety, challenge balance, and maintain compliance. [44, 62-65] A large meta-analysis led by Sherrington et al [18] concluded that falls prevention programs that include a moderate to high challenge to balance are associated with a reduction in falls among community-dwelling older adults. However, when these exercise parameters were introduced to older adults recently discharged from hospital, [44] this led to an increase in the number of falls, falls injuries, and proportion of fallers. The components of the home exercise programs that may assist to explain this effect include no direct supervision or limited one-on-one supervision of the exercises, and recommended frequencies of 30-40 minutes at least 3-6 days per week. Since this population is generally functionally declined, participants may have required more supervision initially, and a lower commencement dosage of exercise.

This review found that cholecalciferol therapy did not significantly reduce falls in older adults discharged from hospital. Although previous reviews have demonstrated a protective effect of cholecalciferol therapy on falls in community-dwelling and institutionalised older adults, [16] some more recent RCTs have concluded a higher risk of falls at higher doses,

particularly for older adults with a previous falls history.[66, 67] Despite the lack of evidence for falls prevention following hospital discharge, falls prevention guidelines recommend at least 800 international units of vitamin D per day for those with proven or suspected vitamin D deficiency, abnormal gait and risk of falls.[68]

Previous reviews have indicated that patient population may impact outcomes of falls prevention interventions, such as older adults who are frail and at risk of functional decline following recent hospital discharge. [15, 19, 22] Critical elements of frailty, such as muscle weakness and malnutrition are associated with falls and functional decline. [69] A multifactorial intervention incorporating an individualised home program for frail older adults improved risk factors for falls but did not reduce rate of falls. [70] One study in this review that provided nutrition supplementation for malnourished older adults was effective in reducing the proportion of people who fell post-discharge, [50] indicating interventions that target elements of frailty are likely to have a positive effect on falls risk factors and falls outcomes. This result is consistent with previous RCTs and systematic reviews [21, 71-73]

Study Strengths and Limitations

This systematic review was a comprehensive undertaking with a large range of falls prevention interventions analysed. Falls prevention interventions that are effective in the general older population may require tailoring to be effective for older adults recently discharged from hospital. There are additional and possibly specific factors to be considered in delivering interventions to this population, including the need for regular supervision and support to aid functional recovery and prevention of hospital re-admission.

Although this review did not find one falls prevention intervention was significantly effective overall, there is a possibility that tailoring different components of the interventions to the identified falls risks, physical and social needs of the older person, could lead to better uptake of falls prevention strategies. Although a large systematic review investigating falls prevention found multi-factorial interventions were implemented in 19 trials, [16] we found no trials that evaluated multi-factorial falls interventions in the post-discharge setting. Targeted multi-dimensional falls risk assessment and management offered by multi-disciplinary specialists for older adults following hospital discharge is warranted. Especially considering current healthcare services tend to discharge older adults from hospital with ongoing medical illnesses, frailty and risk of further falls. This is a consideration for future research as multi-factorial falls interventions have been shown to be effective for falls prevention of older adults in the community setting. [16]

A possible limitation of this review is the grouping of interventions that necessitated simplification of often complex interventions. The analysis is based on overall effects of the intervention categories, without consideration of characteristics of individual participants, modification of intervention doses, or adherence to interventions.

Despite efforts to be comprehensive in our choice of search terms, we did not cover all MeSH terms such as “elderly” and “seniors”, and so there is potential that studies were not found during our search strategy and screening process. However, the MeSH terms used in our search include “frail elderly” as well as people “aged 65 to 79 years”, and during the final search phase, we hand-searched reference lists of all studies examined in full text to strengthen our search.

Conclusion

Falls are a serious problem for older adults who have recently been discharged from hospital, with associated decline in quality of life and functional independence. [9-13] Falls prevention interventions found to be effective in the general older population are not necessarily transferrable to older adults following hospital discharge.

We found low to moderate quality GRADE evidence following data-analysis from studies grouped according to interventions. The recommended falls prevention interventions for older adults recently discharged from hospital are to provide home hazard minimisation particularly if they have a recent previous falls history and consider nutritional supplementation if they are malnourished. Future randomised controlled trials to investigate the post-discharge falls prevention effects of tailored education, multi-factorial falls interventions and structured supervised exercise programs are warranted. Falls prevention interventions for this population may need to be tailored to the individual older patient, with planned review after hospital discharge to support uptake of falls prevention strategies.

KEY POINTS

- There is a range of falls interventions delivered in a limited number of small studies for the post-discharge older population with potential high risk of bias.
- Falls prevention interventions effective in the general older population are not automatically transferrable in the post-discharge setting and may need to be tailored to the individual older patient, with post-discharge review to support uptake.
- Recommendations based on the evidence are to implement home hazard minimisation particularly if there is a history of recent falls and consider nutritional supplementation if the older adult is malnourished.

- Future research to investigate the post-discharge falls prevention effects of tailored education, multi-factorial interventions, and structured supervised exercise programs is warranted.

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Conflict of Interest

The authors have no conflict of interest to disclose.

Author Contributions

All authors meet the criteria for authorship stated in the Uniform Requirements for Manuscripts Submitted to Biomedical Journals.

Sources of Funding

The authors have not received financial support for this study.

FIGURE LEGEND

Figure 1 Study Selection Flow Chart

Figure 2. Forest Plots (Pooled) Overall Effect of Home Exercise on Falls Outcomes

Figure 3. Forest Plots (Un-pooled) Effect of Interventions on Falls Rate and Proportion of People Who Fell

TABLE LEGEND

Table 1 GRADE Summary of the evidence

SUPPLEMENTARY APPENDICES

Supplementary Appendix 1 Search strategy and Information sources

Supplementary Appendix 2 Critical appraisal instrument

Supplementary Appendix 3 Characteristics of included studies

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Supplementary Appendix 4 Full Reference list

Supplementary Appendix 5 Study population

Supplementary Appendix 6 Critical appraisal of included studies

Supplementary Appendix 7 Forest plots

Supplementary Appendix 8 Effectiveness of falls prevention interventions

Authors Original Version

SUPPLEMENTARY APPENDIX 1: Search strategy and information sources

Search strategy using PubMed terminology

Search	Key word		Key word		Key word
1.	accidental fall	AND	older	AND	post-hospital
2.			age*		post-hospital
3.			older		hospital discharge
4.			age*		hospital discharge
5.			older		after hospital
6.			age*		after hospital
7.	fall*	AND	older	AND	post-hospital
8.			age*		post-hospital
9.			older		hospital discharge
10.			age*		hospital discharge
11.			older		after hospital
12.			age*		after hospital
13.	intervention*	AND	older	AND	post-hospital
14.			age*		post-hospital
15.			older		hospital discharge
16.			age*		hospital discharge
17.			older		after hospital
18.			age*		after hospital
19.	prevent*	AND	older	AND	post-hospital

20.	age*	post-hospital
21.	older	hospital discharge
22.	age*	hospital discharge
23.		after hospital
24.		after hospital

Information sources

A three-step search strategy was conducted using MeSH terminology and keywords to ensure all relevant studies were captured. At stage one the first author conducted a search of MEDLINE (Ovid), PubMed and CINAHL Plus with full text (EBSCO) using key words accidental fall, fall, intervention; and prevent combined with post-hospital, after hospital, hospital discharge; and older and age (Table 1). Text words in the title and abstract of the identified studies together with index terms describing these studies were used in five further databases: the Cochrane Central Register of Controlled Trials (CENTRAL) (The Cochrane Library), The JBI Database of Systematic Reviews and Implementation Reports, EMBASE, AMED and Psych INFO. Unpublished studies were sought by conducting an electronic search of trials registers Current Controlled Trials (<http://www.controlled-trials.com>) and the National Institute of Health Clinical Database (<http://clinicaltrials.gov>), Universal Index of Doctoral Dissertations in Progress, Mednar, Grey Literature Report and Google. Additionally, hand searches of reference lists of all identified studies were performed.

Stage two of study selection involved a full screening of the abstracts by the first author (CN), then in stage three eligibility assessment was performed by two reviewers using full text retrieval. A third reviewer was available for final consensus.

SUPPLEMENTARY APPENDIX 2

JBI Critical Appraisal Checklist for Randomised Control / Pseudo-randomised Trial

Reviewer _____ Date _____

Author _____ Year _____ Record Number _____

	Yes	No	Unclear	Not Applicable
1. Was the assignment to treatment groups truly random?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
2. Were participants blinded to treatment allocation?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
3. Was allocation to treatment groups concealed from the allocator?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
4. Were the outcomes of people who withdrew described and included in the analysis?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
5. Were those assessing outcomes blind to the treatment allocation?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
6. Were the control and treatment groups comparable at entry?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
7. Were groups treated identically other than for the named interventions	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
8. Were outcomes measured in the same way for all groups?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
9. Were outcomes measured in a reliable way?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
10. Was appropriate statistical analysis used?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Overall appraisal: Include ☐ Exclude ☐ Seek further info. ☐

Comments (Including reason for exclusion)

SUPPLEMENTARY APPENDIX 3 Characteristics of included studies

Study *	Population†	Therapy, Dose, Frequency	N (I, C)	Mean age, Female% Drop-out%	F/Up, months setting	How falls assessed	Incident Rate Ratio Total Falls (95% CI)	Incident Rate Ratio of Falls Injuries (95% CI)	Risk Ratio of Fallers (95% CI)
Batchelor et al. ⁵⁴ Australia	Recent stroke and assessed high falls risk	I: 1. PT HEP (Otago), 30-40min, 3-5x/week 2. Falls advice based on FROP-Com ⁵⁶ C: UC	156 (64, 80)	70, 36.5%, 15%	12 HV	Monthly FD mailed	1.10(0.63,1.90)	1.57 (0.73, 3.4)	0.83(0.60, 1.14)
Berggren et al. ⁴⁹ Sweden	Post-repair hip fracture	I: GMT in hospital then AH P/C 2weeks post-d/c offered rehabilitation in home or DH C: UC	199 (102, 97)	82, 74%, 20%	12‡HV	MR in hospital & during F/Up HV	12months 0.64(0.40, 1.02)	n/a	n/a
Bischoff-Ferrari et al. ^{48§} Switzerland	Post-repair hip fracture	I: PT HEP C: no HEP	173 (87, 86)	84, 79.2%, 26%	6 & 12 HV	Monthly PC & FD	0.75 (0.56,0.99)	n/a	n/a
Bischoff-Ferrari et al. ^{48§} Switzerland	Post-repair hip fracture	I: Vit D 2000IU/day for 12 months C: Vit D 800IU/day for 12 months	173 (86, 87)	84,79.2%,2 6%	6 & 12 HV	Monthly PC & FD	1.28 (0.96, 1.68)	n/a	n/a
Cumming et al. ⁴² Australia	Post-rehabilitation	I: OT HV & HHM recommendations monitored at 2 weeks C: UC	530 (264, 266)	77, 57%, 27%	12 HV or PC	Monthly FD mailed	n/a	n/a	1.27 (0.9, 1.8)
Di Monaco et al. ^{40*} Italy	Recent hip fracture	I: Single HV by OT suggestions for HHM C: UC	95 (58, 61)	80, 100%, 7%	6 HV	6-month HV VR	n/a	n/a	OR 0.275 (0.08, 0.94)
Di Monaco et al. ⁴⁷ Italy	Recent hip fracture	I: Single OT PC to recommend HHM C: UC	169 (78, 75)	78, 100%, 9.5%	6 PC	6-month PC VR	n/a	n/a	1.06 (0.48, 2.34)
Haines et al. ⁵³ Australia	Post-d/c geriatric, surgical or medical	I: HEP using Kitchen table +DVD +workbook delivered by PT in home monitored weekly for 8weeks (P/C or HV) C: UC	53 (19, 34)	80, 60%, 5.7%	2 & 6 clinic or PC	Monthly PC & FD	0.72 (0.33,1. 57)	Fracture: 0.88 (0.08, 9.7)	0.96 (0.31, 3.00)
Hauer et al. ⁴⁶ Germany	Post d/c from falls-related rehabilitation	I: DH Ex 3days/week for 12 weeks C: Placebo ex group	57 (31, 26)	82, 100%, 21%	3 & 6 clinic	Fortnightly FD and VR in clinic	0.75 (0.45, 1.24)	n/a	n/a
Hill et al. ⁴¹ Australia	Older inpatients	I: Tailored education focussed on post-discharge falls prevention C: UC	50 (25, 25)	78, 64%, 2%	1 PC	1 Month PC	0.29 (0.08, 1.05)	0.23 (0.03, 1.63)	0.33 (0.08, 1.33)
Hill et al. ¹⁴ Australia	Older inpatients	I: Inpatient falls prevention education Materials only self-directed workbook and DVD. Complete: Materials + Health professional tailored education C: UC	343 (Mat 123, Complete 120, Control 100)	79.4, 61.2%, 11%	6 PC	Monthly PC & FD	Mat only 1.48(0.95, 2.30) Compl1.18(0.71, 1.96)	Mat only 1.36 (0.80, 2.30) Compl1.00 (0.60, 1.66)	Mat only 2.12(1.21, 3.70) Compl1.3 4(0.76, 2.37)
Huang & Liang ⁴⁵ Taiwan	Recent hip fracture	I: d/c plan + brochure + social supports+ HV at 1-week post-d/c by Nurse+ weekly PC 3 months C: UC (no brochures or HVs)	126 (63, 63)	75, 69%, 3%	2 & 12 weeks HV	Weekly PC & FD	n/a	n/a	n/a
Latham et al. ^{52§} Australia & New Zealand	Frail older people	I: High intensity quadriceps resistance HEP using ankle weights 3 times per week for 10 weeks C: Frequency matched HV	243 (112, 110)	79, 53%, 5.6%	3 & 6 HV	FD & weekly PC	0.96 (0.67, 1.36)	n/a	n/a

Latham et al. ⁵³ § Australia & New Zealand	Frail older people	I: Single dose Vit D, 300,000IU C: placebo tablets	243 (108, 114)	79, 53%, 5.6%	3 & 6 HV	FD & weekly PC	1.12 (0.79, 1.59)	n/a	n/a
Neelmaat et al. ⁵⁰ Netherlands	Malnourished older people	I: Nutritional supplementation (energy + protein + 400IU VitD)/day + weekly phone counselling for 3 months C: UC	210 (105, 105)	74, 58%, 30%	6 & 12 weeks	FD 6 and 12 weeks	n/a	n/a	0.41 (0.19, 0.86)
Nikolaus & Bach ⁴³ Germany	Older inpatients	I: HIT HV + HHM recommended and monitored at 3 months C: Geriatric assessment	360 (181, 179)	81.5, 73.3%, 5%	3 & 12 HV	Monthly PC & FD	0.69 (0.51, 0.97)	n/a	n/a
Sherrington et al ⁴⁴ Australia	Older inpatients	PT prescribed HEP using Better Balance Program + workbook, unsupervised recommended 6 times per week for 20-30minutes.10 HV over 12 months to monitor C: UC+ falls prevention booklet	340 (171,169)	81.2, 74%, 7%	3 & 12 HV	Monthly FD	1.43 (1.07,1.93)	1.14 (0.76, 1.73)	1.38 (1.11, 1.73)
Treacy et al. ⁵¹ Australia	Older rehabilitation patients	I: Inpatient balance circuit class 6 x 1-hour sessions over 2 weeks supervised by PT C: no class	162 (81, 81)	82, 52%, 14%	2 weeks and 3 months clinic	VR at 2 weeks and 3 months clinic	1.13 (0.64, 1.96)	n/a	n/a

*RCT except Di Monaco et al⁴⁰ is a quasi RCT † Community-dwelling older adults recruited from hospital **I** Intervention **C** Control **PT** Physiotherapist **HEP** Home exercise program **FROP-Com** Falls risk assessment tool for older people in the community [56] **UC** usual care **F/Up** Follow-up **FD** Falls diary **CI** Confidence interval **n/a** not available from the study **DH** Day hospital **GMT** Geriatric management team **AH** Allied Health ‡from day of hospital admission **d/c** discharge **MR** Medical records **HV** Home visit §Factorial designed RCT **VitD** Vitamin D **PC** Phone-call **OT** Occupational therapist **HHM** Home hazards modification **DH Ex** Day hospital strength and balance exercise program **VR** Verbal reports + plus **HIT** Home intervention team, consists of either a PT or OT and a Nurse

SUPPLEMENTARY APPENDIX 4: Full Reference list

*denotes study included in the systematic review

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SUPPLEMENTARY APPENDIX 5: Study Population

The articles included in the review comprised 15 RCTs and one quasi RCT. [40] Eight of the studies were conducted in Australia [14, 41, 42, 44, 51, 52, 53, 54], two in Germany, [46, 43] and Italy, [40, 47] one in Switzerland, [48] Taiwan, [45] Netherlands [50] and Sweden. [49] The sample sizes ranged from 50 [41] to 530, [42] with a total sample size of 3290. The mean age across the 16 studies was 77 years, with an age range of 70-84. The total number of participants that completed baseline assessment was 3,290 and 2,729 completed final assessments across the 16 studies, with an average retention rate of 83%. The largest drop-out

rate was 30%, [50] with 70% of participants retained over a three-month study duration, however this drop-out rate could be explained by the frailty of the population (participants were malnourished). The lowest drop-out rate was 7.4% in a study of one year's duration. [44]

All the selected studies' sample populations consisted of older adults recruited from inpatient wards, 6 of the studies followed patients with a hip fracture, [40, 45, 47-49] 9 followed patients from a rehabilitation ward [14, 40-44, 49-53], and 1 study followed patients who had a diagnosis of stroke from a stroke ward. [54] Twelve studies excluded older adults with cognitive impairment. [14, 40-47, 49, 52, 53] All studies' populations consisted of participants that were discharged home to the community and 4 studies also included 5-17% of participants who were discharged to a residential care setting. [14, 50-52] One study population consisted of 37% of participants discharged to a residential care setting [49] and one study did not specify discharge destination in the inclusion criteria or baseline characteristics. [51]

There was a wide range of baseline characteristics measured across the studies (see Supplementary Appendix 3). Falls risk factors such as number of falls in 1 year prior to admission or inpatient falls, gait, mobility and cognition were recorded in most included studies baseline characteristics. Three studies did not record number of inpatient falls prior to discharge. [47, 48, 50] As an established clinical predictor of falls following hospital discharge, [74, 75] this would ideally have been required during selection and randomisation to avoid selection bias. [76]

SUPPLEMENTARY APPENDIX 6:

Critical Appraisal of all studies

Study	Adequate sequence generation described	Participant allocation blinding described	Allocation concealment described	Incomplete outcome data addressed	Assessor blinding	Similar baseline characteristics	Groups treated identically other than named interventions	Outcomes measured same for groups	Outcomes measured reliably	Appropriate statistical analysis used
Batchelor et al, 2010	Y	N	Y	Y	Y	Y	N	Y	Y	Y
Berggren et al, 2008	Y	U	Y	Y	N	Y	Y	Y	Y	Y
Bischoff-Ferrari et al, 2010	Y	N	Y	Y	Y	Y	Y	Y	Y	Y
Cumming et al, 1999	Y	U	Y	Y	Y	Y	Y	Y	Y	Y
Di Monaco et al, 2008	U	N	N	Y	N	Y	Y	Y	N	Y
Di Monaco et al, 2015	Y	N	Y	Y	Y	Y	Y	Y	Y	Y
Haines et al, 2009	Y	Y	Y	Y	Y	N	Y	Y	Y	Y
Hauer et al, 2001	U	N	U	Y	Y	Y	Y	Y	Y	Y
Hill et al, 2011	Y	N	Y	Y	Y	Y	Y	Y	Y	Y
Hill et al, 2013	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Huang & Liang, 2005	Y	N	Y	Y	N	Y	N	Y	U	U
Latham et al, 2003	Y	N	Y	Y	Y	Y	Y	Y	Y	Y
Neelmaat et al, 2012	Y	N	Y	Y	Y	Y	Y	Y	Y	Y
Nikolaus & Bach, 2003	Y	U	Y	Y	Y	Y	Y	Y	Y	Y

Sherrington et al, 2014	Y	N	Y	Y	Y	Y	Y	Y	Y	Y
Treacy et al, 2015	Y	N	Y	Y	Y	Y	U	Y	Y	Y

Key: Y- Yes; N-No; U-Unclear

Quality of studies

There were 14 studies that satisfied concealed random allocation of participants to intervention and control groups, two studies being unclear in their description of randomisation, sequencing, allocation and concealment. [40, 46] Only 2 studies were compliant in blinding of participants, [41, 53] while all studies consistently showed an intention to treat and included loss to follow-up data in the analysis. Three studies did not maintain blinding of outcome assessors, [40, 45, 49] introducing the potential for selective outcome reporting bias. [76] The remaining studies followed international recommendations of reporting falls outcomes, with daily prospective falls reporting using a falls diary coupled with details about falls through a phone call at least once per month. [28]

Studies excluded from meta-analysis following critical appraisal

The trial led by Huang and Liang, [45] provided a discharge plan for older adults in Taiwan returning home from hospital following a falls related hip fracture, and secondary falls outcomes measured were limited to the proportion (number) of fallers and did not include incidence of falls or injurious falls. The study did not limit potential risk of bias as some participants moved between families to enable sharing of carer responsibility – this may have affected the outcomes and blinding of outcome assessors. Due to these disparities in quality, the study was subsequently removed from the meta-analysis.

The study led by DiMonaco [40] was the only quasi RCT included in the review. This study evaluated occupational therapy home visits for falls prevention by obtaining falls data verbally and retrospectively from participants at the 6-month follow-up home visit. The JBI critical appraisal tool for quasi-experimental studies accommodates an absence of random allocation, however there is still a requirement for outcomes to be measured in a reliable way, and at multiple time points after the intervention is complete. As this study did not measure falls in accordance with recommended guidelines and obtained follow-up data on only one occasion at 6 months post-discharge, it had reduced power to reliably detect falls incidence, [28] hence the study was removed from the meta-analysis.

SUPPLEMENTARY APPENDIX 7:

Forest plots showing un-pooled effects of interventions on falls outcomes at the individual study level

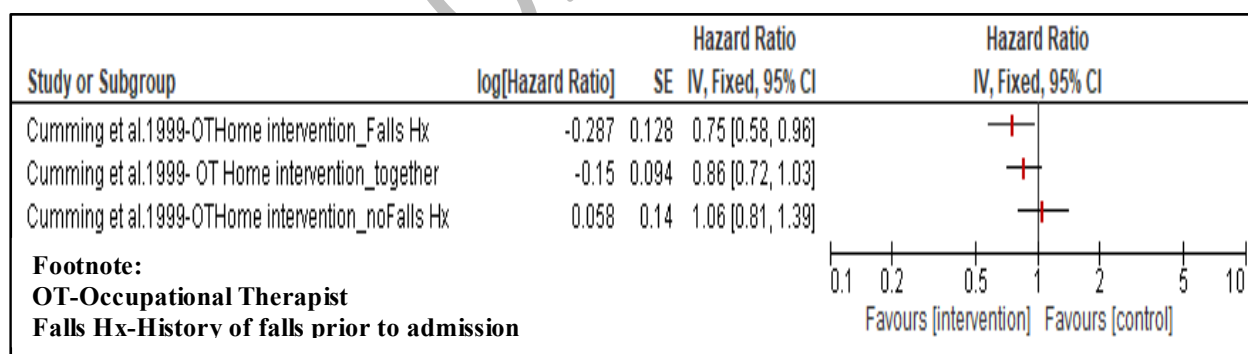


Figure S1: un-pooled effect of home hazard modification on number of people who fell from study led by Cumming et al [42].

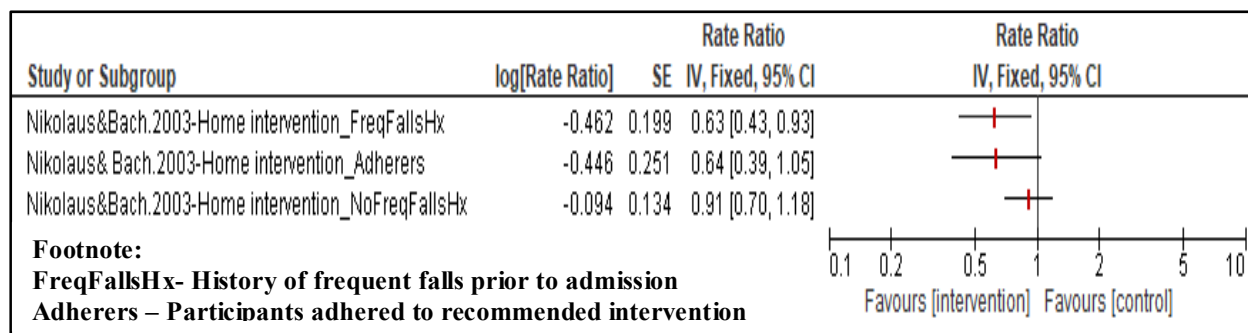


Figure S2: un-pooled effect of home hazard modification on rate of falls in study led by Nikolaus et al [43].

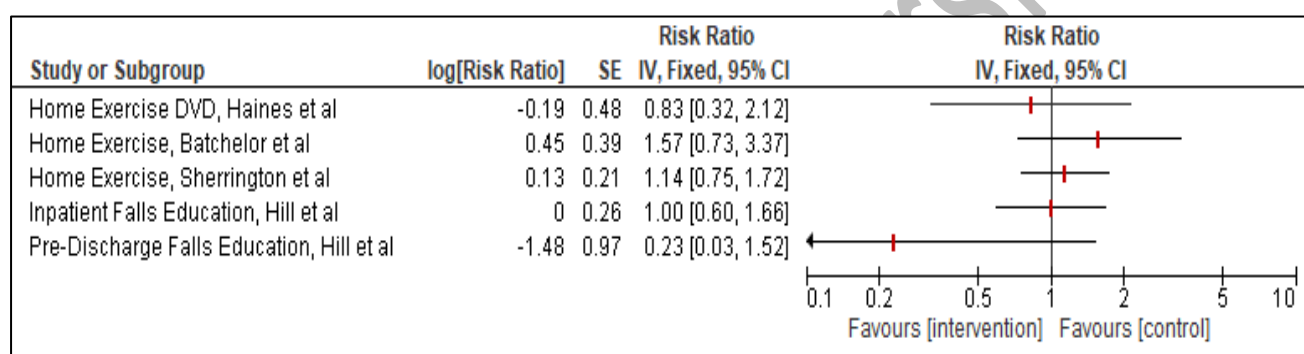


Figure S3: un-pooled effect of various falls prevention interventions on rate of falls injuries

SUPPLEMENTARY APPENDIX 8:

Effectiveness of falls prevention interventions

Cholecalciferol therapy intervention

Two studies were included in analysis of cholecalciferol therapy, one described an increase in rate of falls (per observed patient year) using crude relative rate difference (30, 95% CI -1, 70), the other study described a non-significant effect using raw falls data (number of falls and fallers) and relative risk of a fall (0.96, 95%CI, 0.67, 1.36) though it was unclear if this was formulated based on (study or participant standardized) time or number of participants. The studies differed in falls outcome reporting, dose and duration of cholecalciferol therapy,

one provided a daily high-dose (2000 IU) over one year, whereas the other a single dose (300,000IU), thus results of these studies were not pooled.

Falls prevention education intervention

There were two studies in the review that provided falls prevention education, however the results were not pooled due to differences in the content and intended population of the intervention. One provided inpatient falls prevention education, whereas the other delivered education focused on falls prevention in the period after discharge. The education that focused on inpatient falls prevention had no ongoing effect in the 6 months after discharge. The study that delivered falls prevention education just prior to hospital discharge, was effective in reducing falls rates (RR 0.3, 95% CI, 0.08,1.05), however had no significant effect on falls injury rates, or number of fallers (Figure 3, Figure 4).

Geriatric team management intervention

One study provided geriatric team management, however falls rates were not significantly reduced at the study level, expressed as incident rate ratio (IRR 0.64, 95%CI, 0.40, 1.02) (Figure 3).

Inpatient balance circuit training intervention

One study investigated the efficacy of balance circuit training for inpatients over a 2-week period. Falls rates were reduced in hospital, however this did not carry over to the period following hospital discharge (IRR 1.13, 95% CI, 0.65, 1.98). (Figure 3)

High-intensity quadriceps resistance training intervention

One study implemented a high-intensity quadriceps resistance exercise program in the home for older, frail people following hospital discharge, having no significant overall effect on falls rates after 6 months (RR 0.96, 95% CI, 0.67, 1.36). (Figure 3)

Day hospital strength and balance training intervention

A single study provided strength and balance training in a day hospital setting for 3 days per week for 12 weeks, for older women post hip fracture. Participants in the intervention group demonstrated improvements in strength and function, but no significant falls rate reduction during the 6-month post-discharge period (IRR 0.75, 95% CI, 0.46, 1.25) (Figure 3)

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